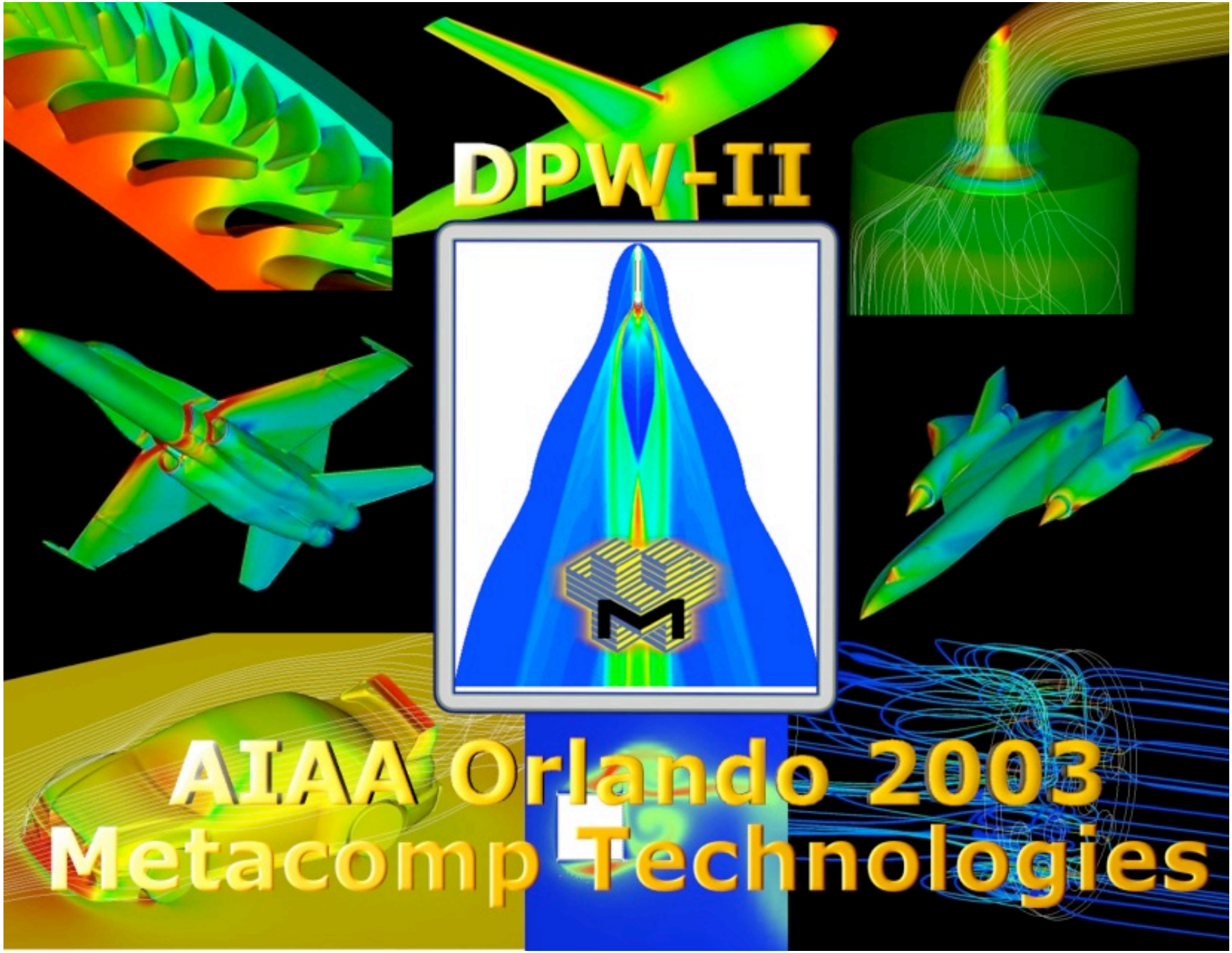
DPW-II
AIAA Orlando 2003
Metacomp Technologies

Drag Prediction Workshop II

PARTICIPANT INFORMATION

The Metacomp Tech. team

represented by:

Uriel Goldberg

e-mail: ucg@metacomptech.com

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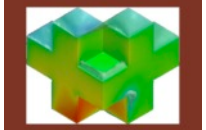
Metacomp Technologies, Inc.

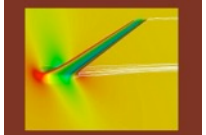
28632B Roadside Drive, # 255

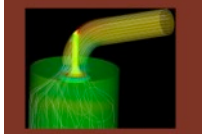
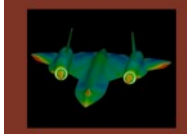
Agoura Hills, CA 91301-3309

CFD++ Solver Information

- **Basic Algorithm: finite volume cell-based mixed-element unstructured**
- **Spatial Discretization: multi-dimensional TVD (inviscid terms), non-decoupling non-limited face polynomials (viscous terms)**
- **Time Integration: point implicit with multi-grid relaxation (for steady state)**
- **Turbulence Model used: wall-distance-free realizable k-□**





Required Cases

CASE 1:

- Hexahedral Mesh
- Single Point Grid Sensitivity Study
- M=0.75, Re=3 M, C_L=0.5
  - W+B+P+N :
    - Coarse Mesh: 4.8M
    - Medium Mesh: 8.5 M
    - Fine Mesh: 12.8 M
  - W+B :
    - Coarse Mesh: 5.5 M
    - Medium Mesh: 7.4 M
    - Fine Mesh: 9.6 M

CASE 2:

- Drag Polars (W+B & W+B+P+N)
  - M=0.75, Re=3 M, □ (deg.) = -3, -2, -1.5, -1, 0, 1, 1.5
- Mesh Information for Case 2:
  - Field Cells: 7.4 M / 8.5 M (WB / WBPN)
  - BL 1st Cell Size: 1.5-2.0E-6 m (y+<1, solve-to-wall)
  - BL Growth Rate: 1.23–1.28
  - BL Cells: ~20

Solution Information

Computer Platform: PIV Xeon 2.4 GHz

Number of Processors: 12

Run Time CPU: 144–160 Hrs.

Run Time Wall-Clock: 12-13 Hrs. (6-8 Hrs. for restarts)

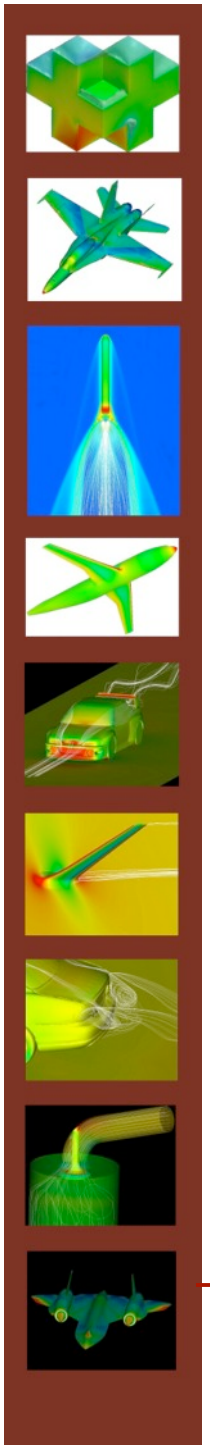
Memory Requirements: ~18 GB

Forces converged in less than 400 time steps

Inflow turbulence levels:

- Turbulence intensity: T'= 0.002 (from AGARD-AR-303)
- Turbulence length-scale: = 0.6 mm (assumed)

Flow was allowed to transition naturally over the wing and fuselage.



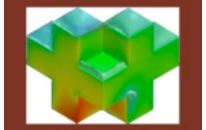
Solution Information

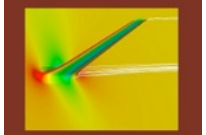
Realizable (to the hilt) k-□ closure

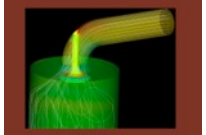
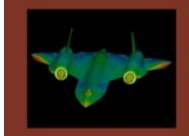
- **Positivity of Reynolds normal stresses:** →
- **Schwartz inequality:** → $\overline{u\,u}^2 \leq \overline{u\,u}\;\overline{u\,u}$ $\quad \square_t \quad \frac{2k}{3|S|}$
- **Time- and velocity-scale realizability:** →
- **Topography-parameter-free formulation**

Sensitizing to non-equilibrium flow →

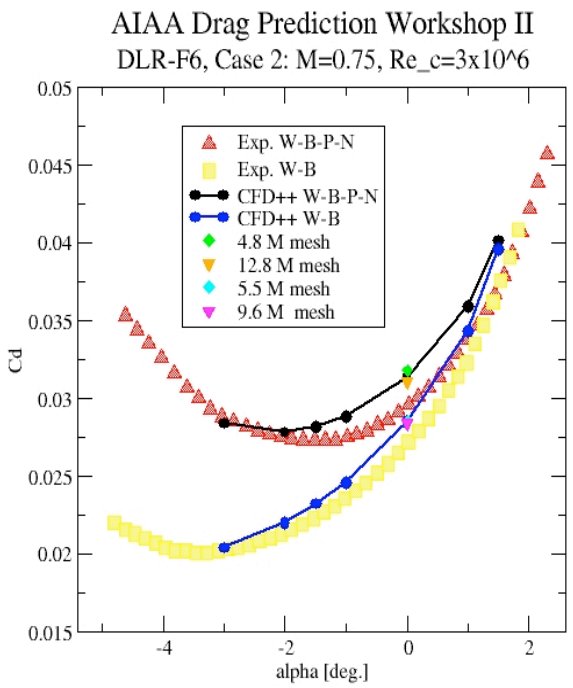
- **Extra source term in □ equation:** $E\square T_{ti}\sqrt{\square}\,\max\left(0,\frac{\partial k}{\partial x_j}\frac{\partial(k/\square)}{\partial x_j}\right)$
- **Increases in non-equilibrium near-wall regions, thereby reducing eddy-viscosity. This improves prediction of backflows for example.**

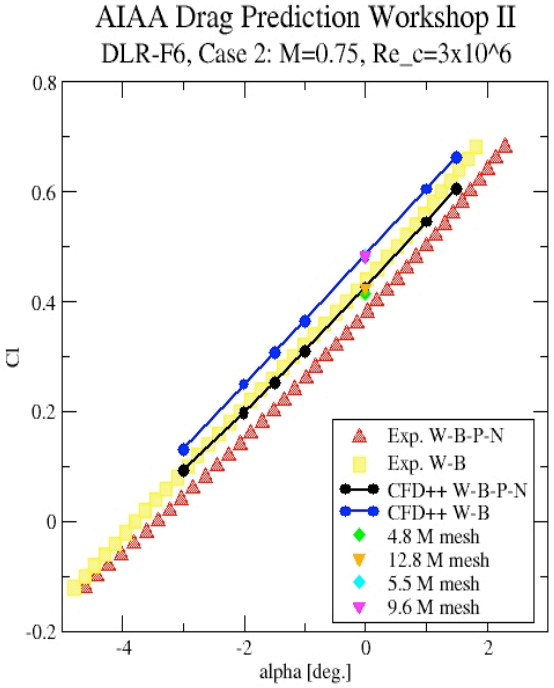


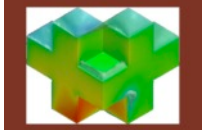


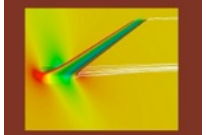



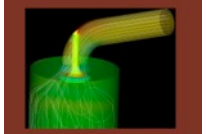
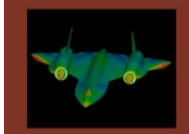
Forces


AIAA Drag Prediction Workshop II
DLR-F6, Case 2: M=0.75, Re_c=3x10^6
Cd
alpha [deg.]
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
-4
-2
0
2
Exp. W-B-P-N
Exp. W-B
CFD++ W-B-P-N
CFD++ W-B
4.8 M mesh
12.8 M mesh
5.5 M mesh
9.6 M mesh

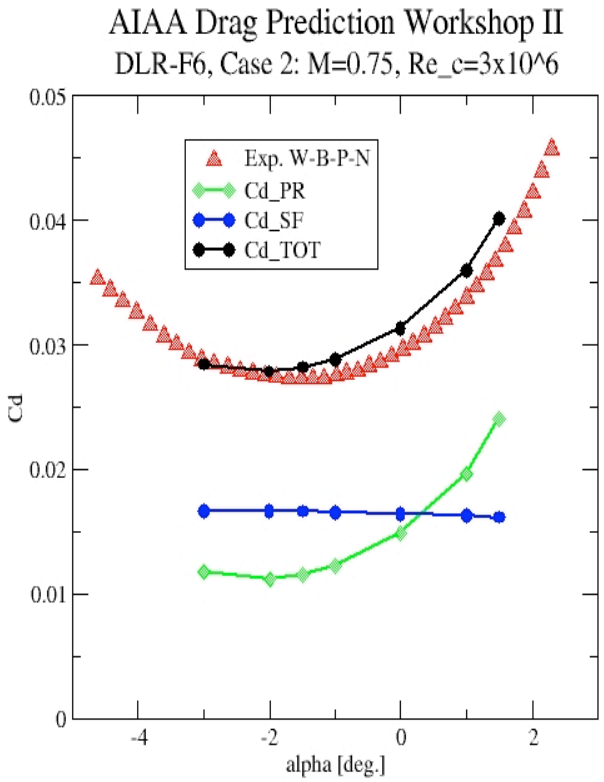

AIAA Drag Prediction Workshop II
DLR-F6, Case 2: M=0.75, Re_c=3x10^6
Cl
alpha [deg.]
0.8
0.6
0.4
0.2
0
-0.2
-4
-2
0
2
Exp. W-B-P-N
Exp. W-B
CFD++ W-B-P-N
CFD++ W-B
4.8 M mesh
12.8 M mesh
5.5 M mesh
9.6 M mesh

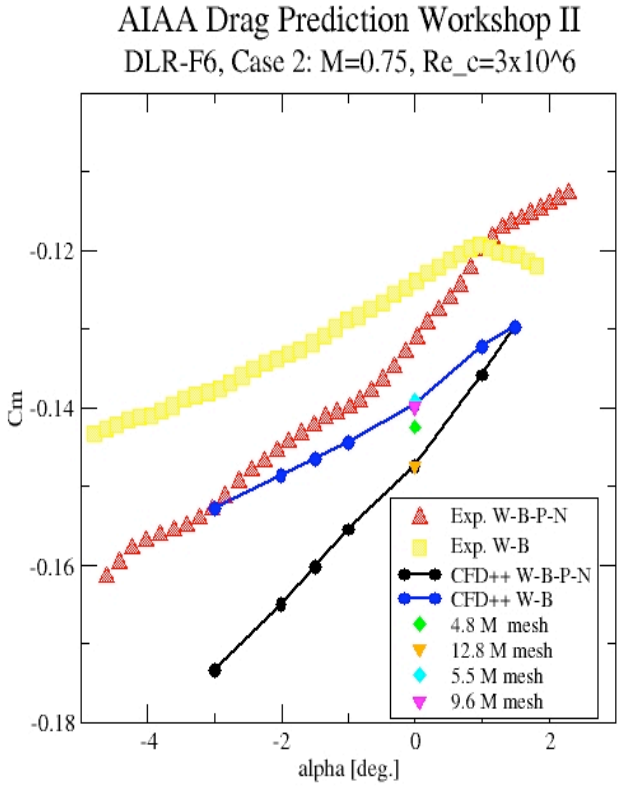


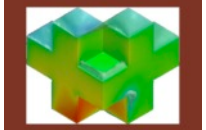


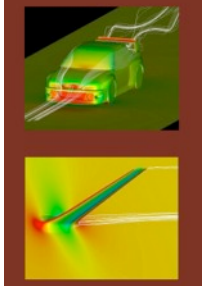



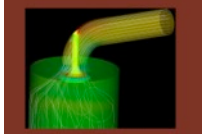
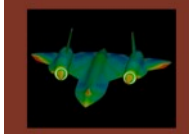
Forces


AIAA Drag Prediction Workshop II
DLR-F6, Case 2: M=0.75, Re_c=3x10^6
Exp. W-B-P-N
Cd_PR
Cd_SF
Cd_TOT
Cd
alpha [deg.]
0.05
0.04
0.03
0.02
0.01
0
-4
-2
0
2

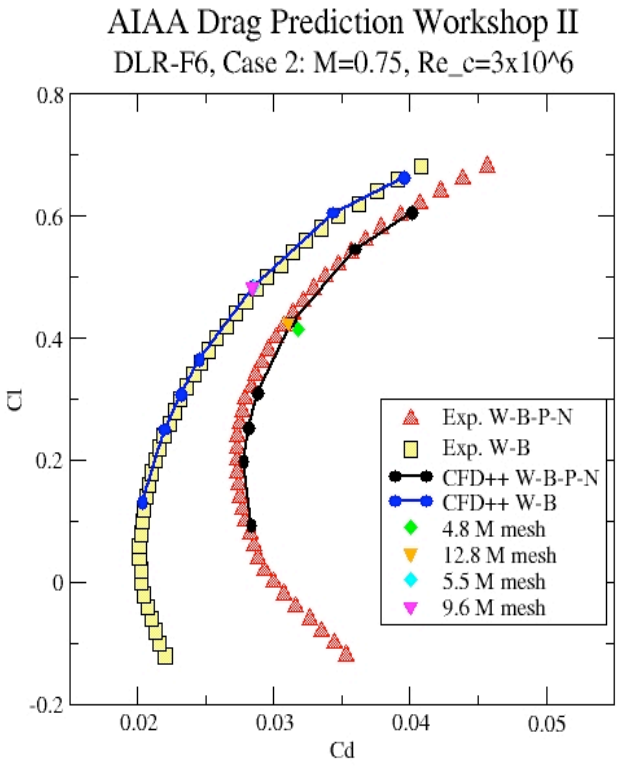

AIAA Drag Prediction Workshop II
DLR-F6, Case 2: M=0.75, Re_c=3x10^6
Exp. W-B-P-N
Exp. W-B
CFD++ W-B-P-N
CFD++ W-B
4.8 M mesh
12.8 M mesh
5.5 M mesh
9.6 M mesh
Cm
alpha [deg.]
-0.12
-0.14
-0.16
-0.18
-4
-2
0
2

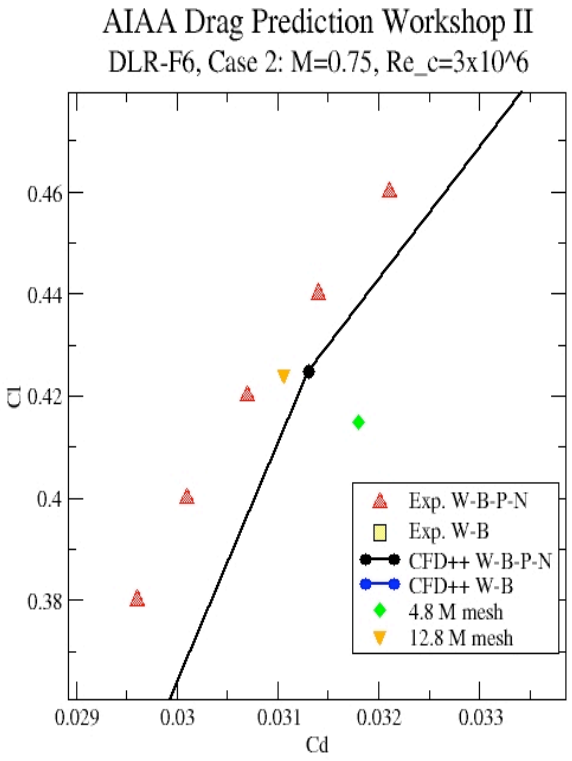


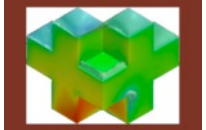


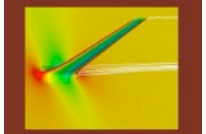



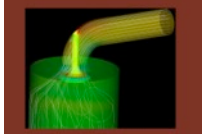
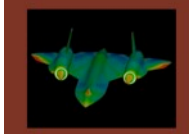
Forces


AIAA Drag Prediction Workshop II
DLR-F6, Case 2: M=0.75, Re_c=3x10^6
Cl
Cd
0.8
0.6
0.4
0.2
0
-0.2
0.02
0.03
0.04
0.05
Exp. W-B-P-N
Exp. W-B
CFD++ W-B-P-N
CFD++ W-B
4.8 M mesh
12.8 M mesh
5.5 M mesh
9.6 M mesh

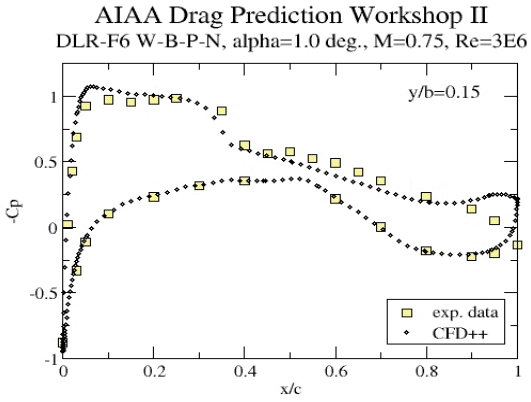

AIAA Drag Prediction Workshop II
DLR-F6, Case 2: M=0.75, Re_c=3x10^6
Cl
Cd
0.46
0.44
0.42
0.4
0.38
0.029
0.03
0.031
0.032
0.033
Exp. W-B-P-N
Exp. W-B
CFD++ W-B-P-N
CFD++ W-B
4.8 M mesh
12.8 M mesh

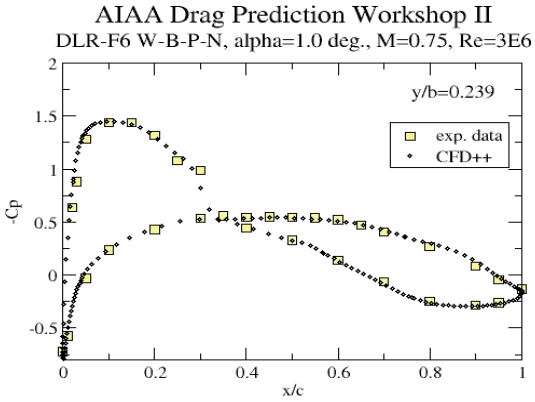




Cp Plots


AIAA Drag Prediction Workshop II
DLR-F6 W-B-P-N, alpha=1.0 deg., M=0.75, Re=3E6
y/b=0.15
exp. data
CFD++
-Cp
x/c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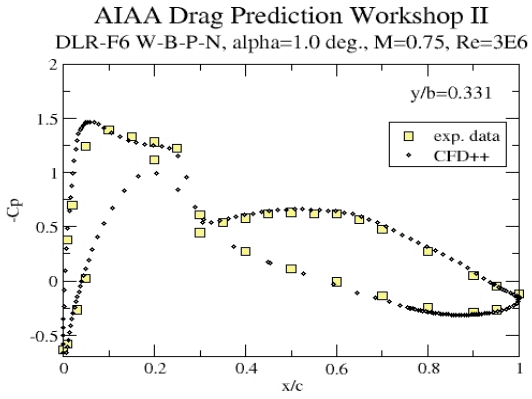
y/b=0.239
exp. data
CFD++
-Cp
x/c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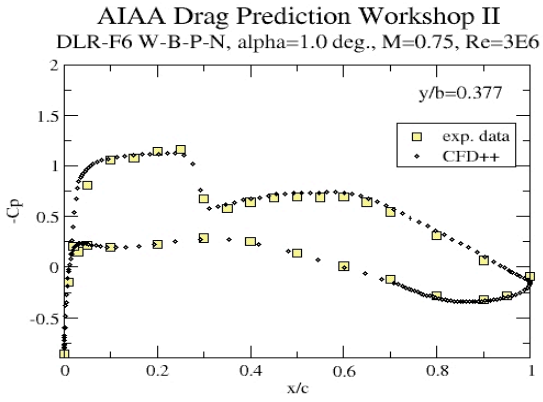
DLR-F6 W-B-P-N, alpha=1.0 deg., M=0.75, Re=3E6
y/b=0.331
exp. data
CFD++
-Cp
x/c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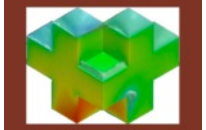
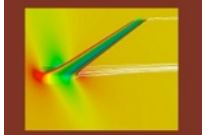
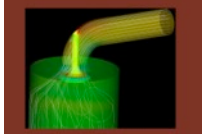
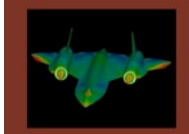
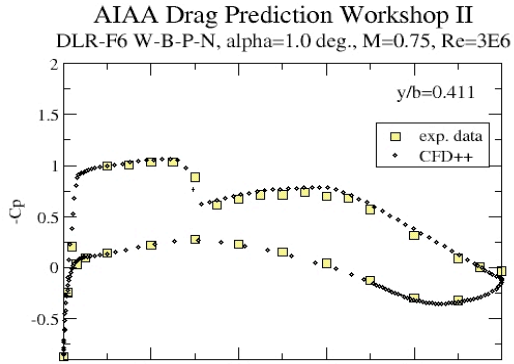
y/b=0.377
exp. data
CFD++
-Cp
x/c

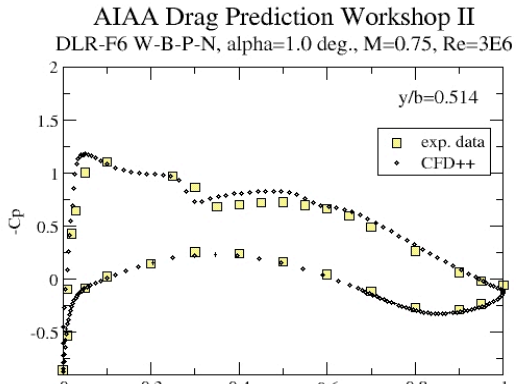


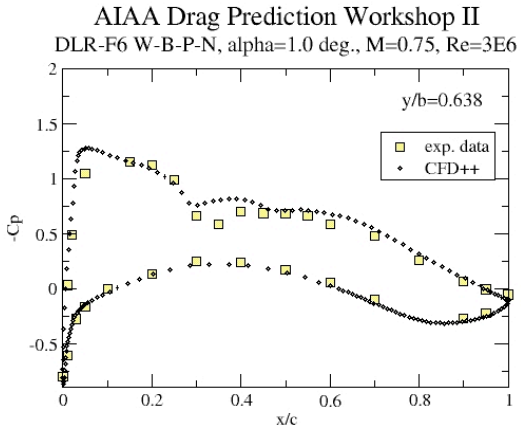


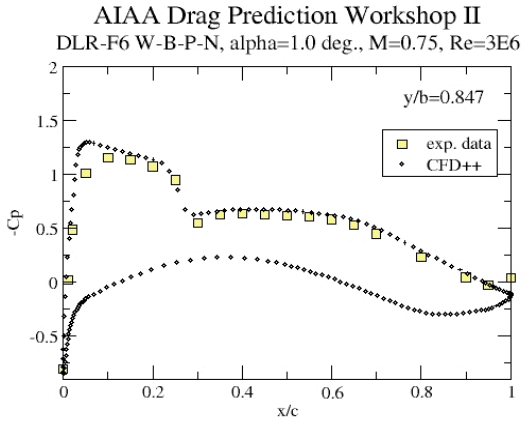



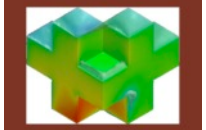
Cp Plots

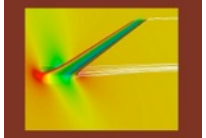

AIAA Drag Prediction Workshop II
DLR-F6 W-B-P-N, alpha=1.0 deg., M=0.75, Re=3E6
y/b=0.411
exp. data
CFD++
-Cp

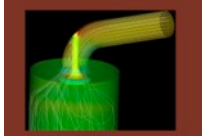
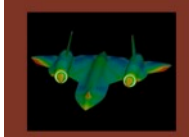

AIAA Drag Prediction Workshop II
DLR-F6 W-B-P-N, alpha=1.0 deg., M=0.75, Re=3E6
y/b=0.514
exp. data
CFD++
-Cp


AIAA Drag Prediction Workshop II
DLR-F6 W-B-P-N, alpha=1.0 deg., M=0.75, Re=3E6
y/b=0.638
exp. data
CFD++
-Cp
x/c

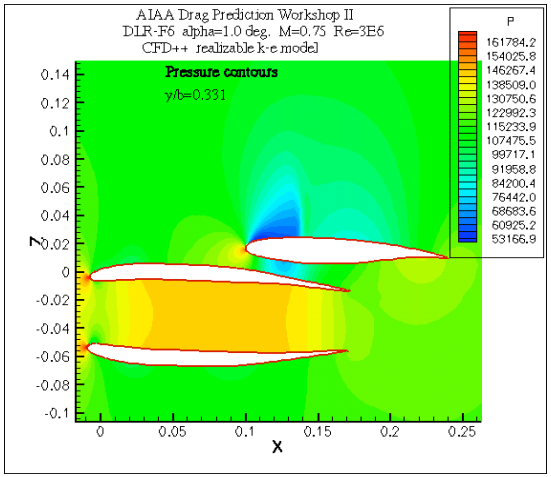

AIAA Drag Prediction Workshop II
DLR-F6 W-B-P-N, alpha=1.0 deg., M=0.75, Re=3E6
y/b=0.847
exp. data
CFD++
-Cp
x/c

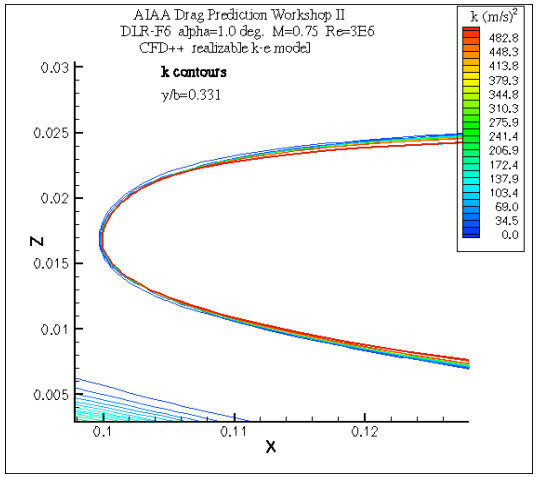


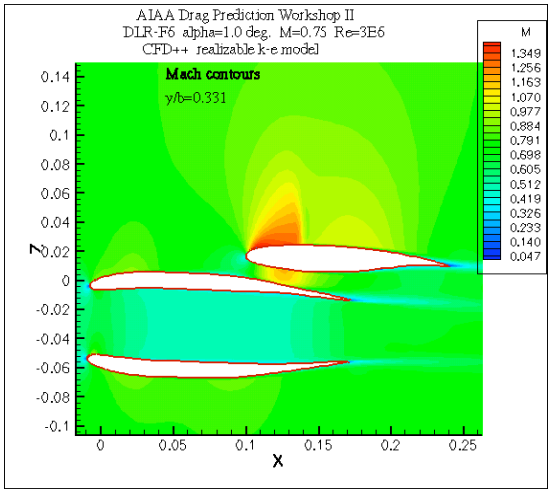


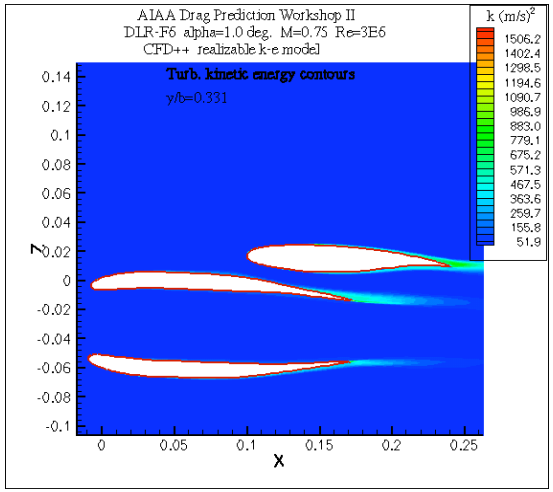



Contour Plots

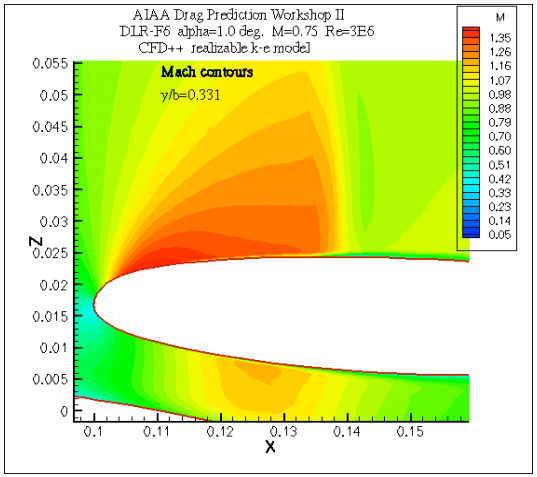


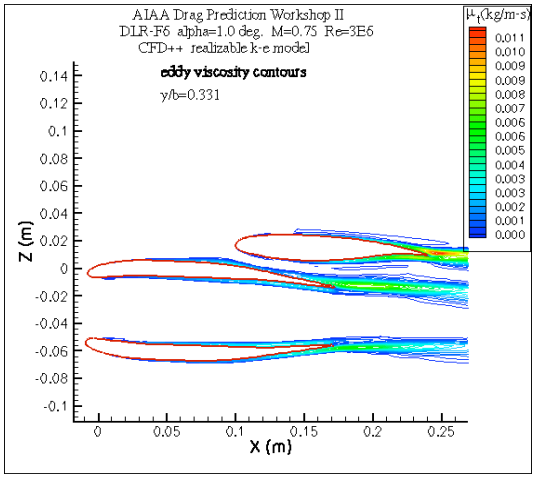


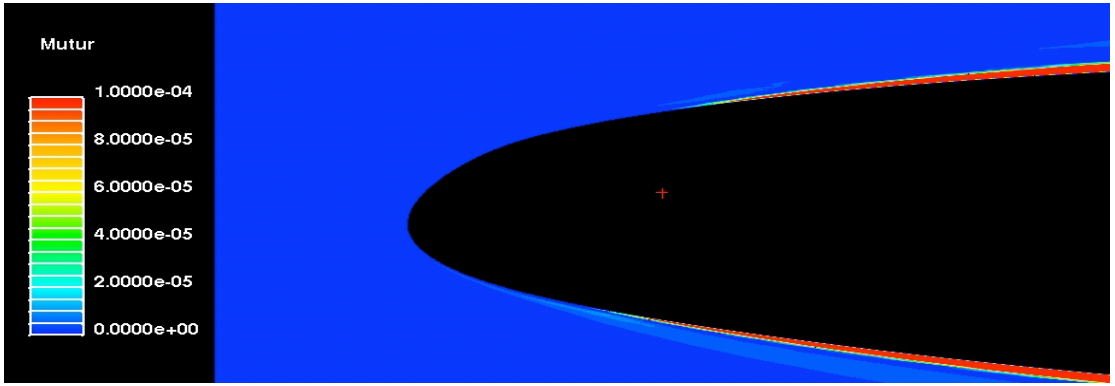




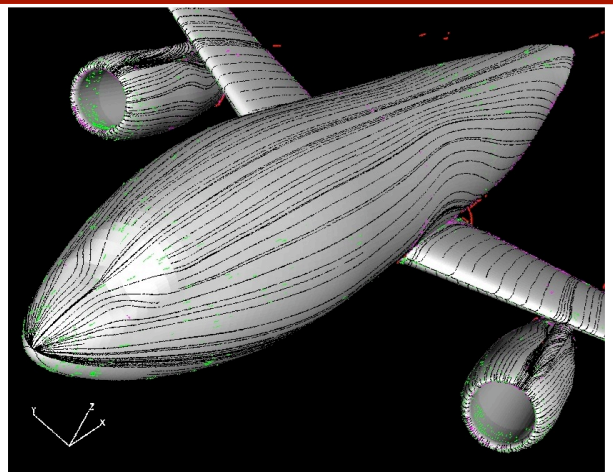
Contour Plots



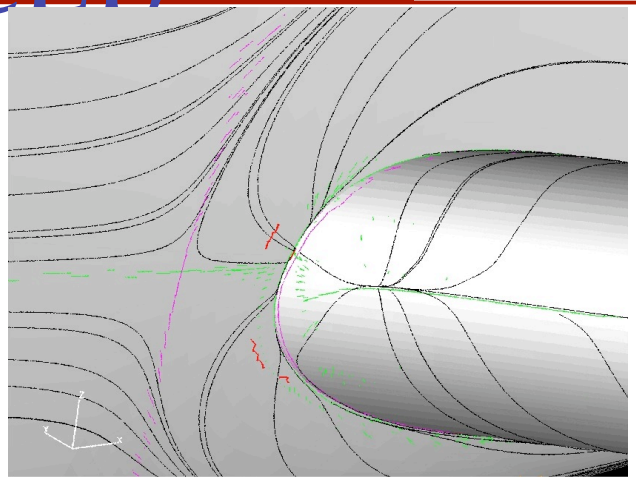


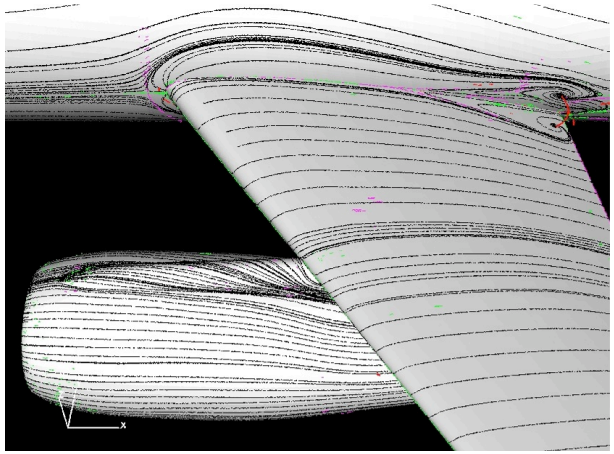


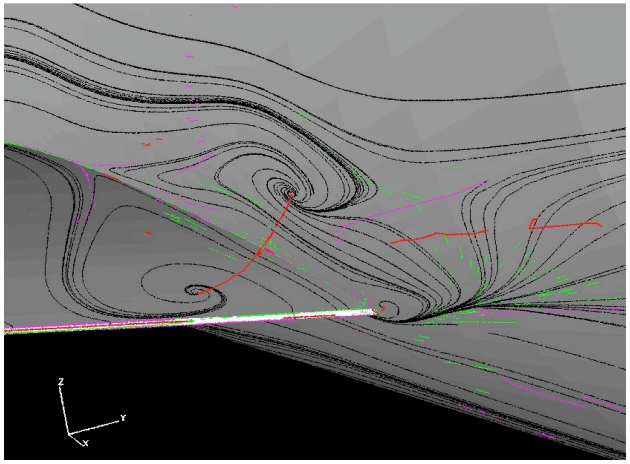
Separation bubble (courtesy: CEI)



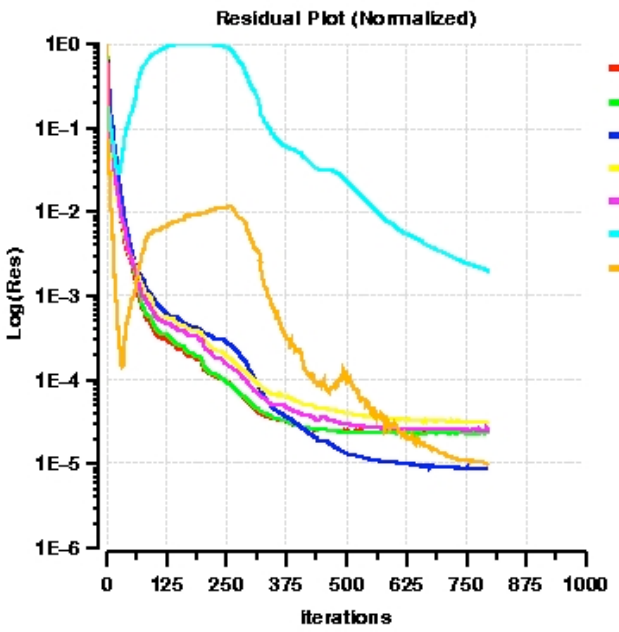
Courtesy: CEI

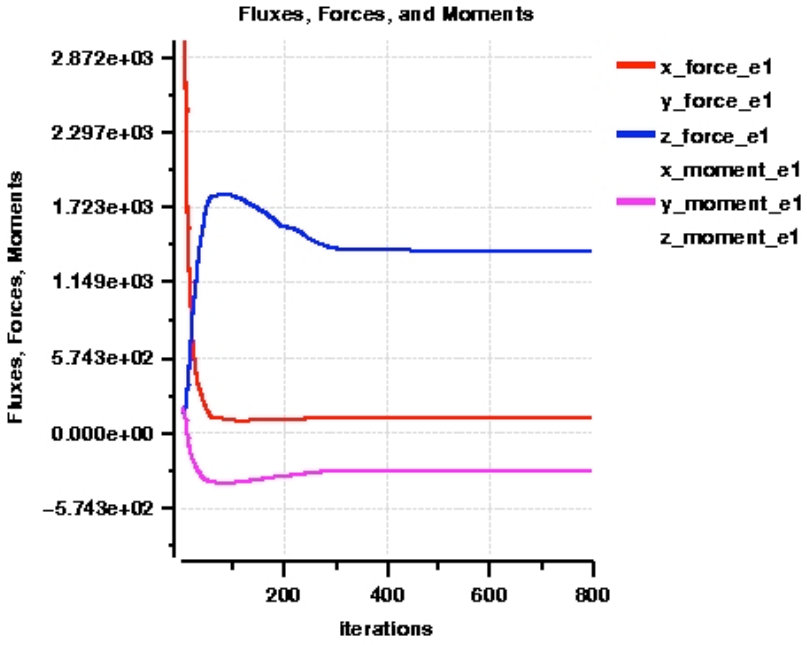


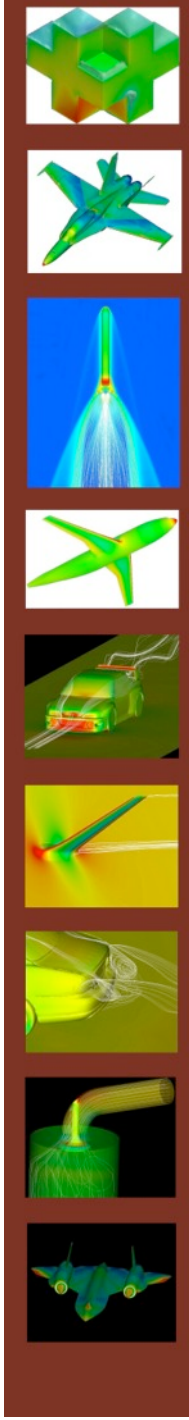




CFD++ Convergence







Conclusions

- **CFD++ took less than 400 steps to converge forces & moments**
- **Fully turbulent computations with natural transition at L.E. regions**
- **Max. Cd deviation: 28 counts (WBPN), 24 counts (WB) at α=1.5 deg. (18 & 14 at 0 deg.)**
- **Cd deviation is due to pressure drag**
- **Good polar predictions for both configurations**

Summary

Together these elements contribute to the overall effectiveness of CFD++